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ABSTRACT

The Corrective Feedback Paradigm (CFP), a computer-based instruction model, addresses the problem of inefficient sequencing of items in a set to be learned by suggesting the use of an increasing ratio review schedule for presenting drill items. With this system, items answered correctly are either removed from the list entirely or replaced at the end of the stack of items; if an incorrect answer is given, the missed item is inserted in the stack of drill items according to a specified spaced review schedule. To determine the effectiveness of increasing ratio review for teaching generalizable concepts, 51 subfreshman, enrolled in one of three Algebra I classes at a university laboratory high school, utilized the PLATO system to study the generalizations suggested by the relationship between the equations for curves. For purposes of the experiment, three drill paradigms were used: (1) increasing ratio review with generalized item generation (IRR-GEN); (2) increasing ratio review with fixed items (IRR-FIX); and (3) immediate review only with generalized item generation (IMM-GEN). Pre- and posttests were given to subjects who were randomly assigned to three treatment groups. It was found that the systematic review of difficult items helped the IRR-GEN subjects to remember the concepts over time better than the immediate review treatment helped the IMM-GEN group. There was also a significant difference in posttest performance between the IRR-FIX and IMM-GEN groups. These differences support the claim that increasing ratio review techniques can be successful in enhancing traditional drills to teach generalizations. PLATO system directions and the study posttest are appended, and a list of references is provided. (JB)

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TEACHING GENERALIZATIONS USING A COMPUTER-BASED DRILL STRATEGY

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INTRODUCTION

Computer-based drill and practice lessons designed to teach paired associates are some of the most commonly used computer-based instructional applications and have important functions in the classroom (Balajthy, 1984; Yates, 1983). The memory capabilities and recordkeeping features of computers suit them particularly well to manage the repetitive tasks necessary in conducting a drill. The basic paired associate drill strategy, while often criticized as being of limited use, has three important features for effective instruction when implemented on computers (Siegel & Davis, 1984):

1. Computer-based drills provide opportunities for individualized instruction.
2. Because items are reviewed contingent on the individual student's performance, computer-based drills provide adaptive instruction.
3. As stated above, drills are an instructional technique for which computers are particularly well-suited.

A strength with a different focus, suggested by Balajthy, is that computer-based drills avoid problems of ego involvement when a student makes repetitive errors in typical classroom environment.

The problem with traditional drill and practice techniques, though, is that, for the most part, they have only been effectively applied to the teaching of paired associates. Because much of what needs to be

taught entails far more than the rote memorization of stimulus-response pairs, this limitation seems to suggest that the potential for computers in education has been overstated. What actually may be the case, however, is that the potential of computer-assisted instruction has not been developed to its fullest instructional capability. The purpose of this research is to use demonstrated effective drill procedures to extend the drill format to the teaching of generalizable skills.

Traditional computerized drills have been greatly enhanced by research in methods to improve the effectiveness and efficiency of drill procedures by optimizing the sequence of item presentation and review. One approach to constructing optimal drill procedures is to use a mathematical learning model for paired associate items (Atkinson, 1972; Atkinson & Crothers, 1964; Dear, Silverman, Estavan, & Atkinson, 1967). This control theory model bases the optimal strategy on the probability at any given time that an item is in a particular state representative of the degree to which it has been learned. Based upon the student's performance, each item is placed in one of three states: unlearned, temporary, or permanent. Items in the unlearned state are never answered correctly, while items in the temporary or permanent states are always answered correctly. Learning is described by a state transition from unlearned to temporary or from temporary to permanent, and forgetting is represented by a change from temporary state to unlearned state. The assignment of items to particular states and the criteria for passing items from one state to the next are the factors which this model tries to optimize. The model makes these decisions based on the ability of the student and the difficulty of the particular item.

Extensive records are continually updated concerning all student responses. These records are then analyzed to estimate each item's difficulty based on the performance by all students on that item. They also provide an estimate of the student's ability based on his response record on all previous items (Atikinson, 1974). The control theory model then determines the optimal sequence using the student's ability level and the sequence of correct and incorrect responses given for the item as parameters. Using a similar model, Park and Tennyson (1980) used on-task information to select the number of examples and a response-sensitive strategy in determining the presentation order of examples in teaching concepts.

While these studies have tried to optimize presentation order within a particular drill set, yet another approach is to optimize the presentation order across individual drill sessions (Merrill & Salisbury, 1984). This technique attempts to optimize the selection of new items and review items from previous sessions for each working pool of drill items, although the items are then just circulated in a typical fashion within each particular drill set. A more empirically guided approach to optimizing drill procedures is the Corrective Feedback Paradigm (CFP) (Siegel & Misselt, 1984). The CFP includes adaptive feedback, discrimination training, and increasing ratio review to optimize the effectiveness of computer-based drills.

As indicated by these studies, the major problem with traditional flash card drills is the inefficient sequencing of items in the set to be learned. In such drills, an item answered incorrectly is placed at the end of the stack of items to be presented, and an item answered

correctly is removed from the stack. This strategy is less than optimal for at least two reasons: (a) when the list of items is large, the student is likely to forget the characteristics of the correct response for a missed item by the time it comes up for review; and (b) when the list of items is small (which happens when a drill is nearing completion), the student will not have had to remember the item for more than a few seconds, which makes it unlikely that he will retain the information over longer periods.

Increasing Ratio Review

Siegel and Misselt's CFP technique addresses these problems by using an increasing ratio review schedule for presenting drill items. In an increasing ratio review drill, items answered correctly are handled just as in traditional drills--they are either removed from the list entirely or are replaced at the end of the stack of items according to the overall retirement criterion for the drill. The difference between CFP and traditional drills becomes apparent in the manner in which missed items (those most difficult for the student) are placed in the drill list for review. When a student gives an incorrect response, the missed item is inserted in the stack of drill items according to a specified spaced review schedule. If, for example, a drill is designed with a one-later, three-later, and five-later review schedule, a missed item is first reviewed one item later in the drill. If it is answered correctly at that position, it is then inserted in the list three items later, and, if it is correct that time, it appears five items later in the list. If an item is answered incorrectly at any review position,

the review sequence is started again beginning with the initial review position. After the item has been answered correctly at each review position, it is then placed at the end of the list to be presented again to satisfy the drill retirement criterion.

Figure 1 illustrates the placement of a single missed item in a one-, three-, five-later increasing ratio review drill. Each letter represents a separate item in the drill (a capital letter indicates an incorrect response). Assuming Item B is missed, it will be reviewed at each of the positions shown, provided that the item is correct at each review position. As the drill proceeds, the difficult item is systematically reviewed following longer intervals and will ultimately be placed at the end of the stack of items. In a traditional drill, the missed item would be immediately placed only at the end of the list.

Because several items are usually missed in a drill, their review schedules are likely to overlap. As different items are missed, determining the next item to be presented becomes a complicated task. Figure 2 shows a sequence in which several items have been answered incorrectly. The sequencing departs a bit from the strict one-, three-, and five-later reviews because conflicts occur between review schedules. When conflicts arise, initial reviews take precedence over later ones. Because of the error on Item G and its one-later review, the five-later review for Item B was delayed by one item. Because of these kinds of conflicts, the specified review parameters actually indicate the earliest possible review. Another complication is evident in the presentation of Item G. When it was missed for a second time (on the three-later review for the first error), the review schedule was begun

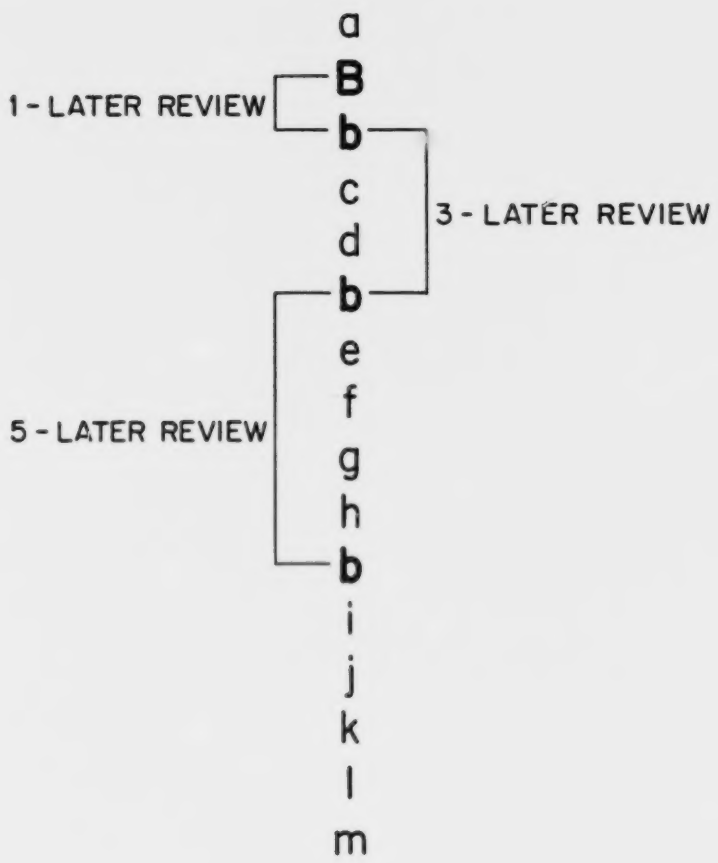


Figure 1. Increasing ratio review of a single missed item in a list of drill items using a one-, three-, five-later review schedule. (An upper case letter indicates an incorrect item.)

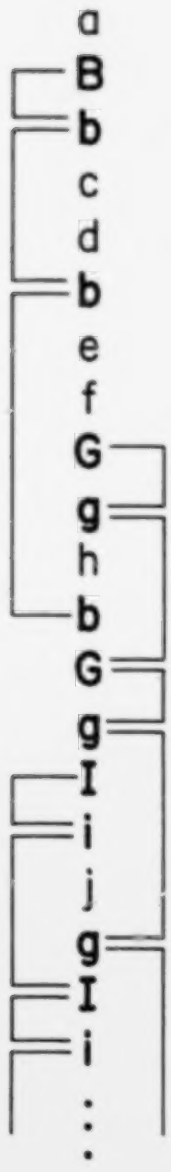


Figure 2. Increasing ratio review of several missed items in a list of drill items using a one-, three-, five-later review schedule. (An upper case letter indicates an incorrect response.

again with one-later review. Although it would be impossible for a human teacher to simultaneously remember the appropriate review positions for many items, computers can perform these recordkeeping tasks with little difficulty.

An increasing ratio review schedule allows the student to remember characteristics of the items from one presentation to the next by using small initial review positions, while shaping long-term retention of items through the gradual increase in the time between repetitions of each item with which the student had difficulty. Siegel and Misselt found CFP increasing ratio review techniques to be more effective than traditional review schedules in teaching Japanese/English vocabulary pairs.

Generalized Drills

Paired associate learning tasks, like foreign language vocabulary lists, are completely dependent on rote memorization of each stimulus and the appropriate paired response. Each pair must be memorized specifically, and knowing one pair does not help in learning any other pair. Most things people learn, however, are concepts (also called generalizations). A concept is a set of specific objects or symbols which are grouped together on the basis of shared characteristics and which can be referenced by the same label or symbol (Merrill & Tennyson, 1977). These samenesses are the critical defining features for the concept (Klausmeier, Ghatala, & Frayer, 1974). These shared characteristics specify the generalization, and the generalization applies to any examples that share these critical features. Learning

the concept requires recognition of the shared characteristics and knowledge that all objects which possess these characteristics may be treated in the same way.

In teaching a generalization, unlike teaching paired associates, no particular instance used to represent a concept is of primary interest. The main objective is to communicate the critical features shared among many examples. For each concept there are countless examples, all of which share the particular sameness that defines the concept (Engelmann & Carnine, 1982; Tiemann & Markle, 1983). The goal in teaching the concept, then, is to communicate the critical sameness that defines the generalization so that the learner will be able to respond correctly to new examples of the concept (Merrill & Tennyson, 1977).

A typical generalization is the class of proper nouns. This is a generalization in that a person who has learned the concept will be able to identify instances not seen before as exemplars of the concept, even though the instances may differ from the examples used in teaching. At one level, the generalization applies to proper nouns in general, and teaching the range would require sampling from the kinds of proper nouns--names of countries, names of states, names of people, etc. But at a greater level of detail, each of these subclasses of proper nouns is also a generalization defined by samenesses among specific exemplars of the subclass. For example, "United Kingdom," "France," and "Mexico" are exemplars of the subclass "names of countries." Alternatively, the original generalization concerning proper nouns can be seen as a single instance of the still broader class--"words that are capitalized." Thus, proper nouns, along with first words in sentences, major words in

titles, etc., would be a subclass of the larger generalization. The important point here is that any concept can be either broken down into more detailed concepts or expanded into a broader generalization to achieve any level of specificity. In teaching a generalization, the particular level of presentation must depend both on the student's conceptual structure of the material and on the instruction's objective.

Because generalizations are learned by identifying the samenesses among the examples experienced by the student, a concept is actually a function of the set of instances that is presented (Engelmann, 1969). There are several possible strategies for selecting the items to be used in an instructional drill on a generalizable concept. One method is simply to select a representative item from each general class that is to be taught. These selected items would form a drill of "n" static items--each item representing a subclass of the generalization.

A drill to teach capitalization of proper nouns would have several subordinate classes: foreign countries, state names, days of the week, etc. In a fixed item drill as described here, a single "typical" example would be selected from the set of possible items for each of the subclasses. These selected items would constitute all the teaching items used, both in initial presentation and in review positions. If "France" were selected as the drill item for the foreign country class, each time the student performed a foreign country capitalization task, the student would have to perform on the item "France." To the extent that the student was knowledgeable about the range of the subclasses, this strategy might be suitable for teaching capitalization of proper nouns in its general sense, because the items do sample the range of the

concept. For a student without an understanding of the subclasses represented by the actual items (without knowledge of the variable attributes), this stipulation of examples makes it unlikely that the student would be able to generalize across the actual range of application of the subordinate concept. From this instruction, there is no reason to suspect that the student would know that the name of any country should be capitalized. It is far more likely that he would have memorized the fact that "France" always begins with an upper case letter, or some other misrule. The student would have formed an undergeneralization--the failure to include some true instances of the concept as examples of the generalization.

The strategy outlined above assumes that mastery of one instance will transfer to all instances of the concept. However, one example will never be entirely representative of a general class--if it were, there would be no generalization to learn. So this item selection technique may be ineffective in that it fails to explore the full range of each generalization.

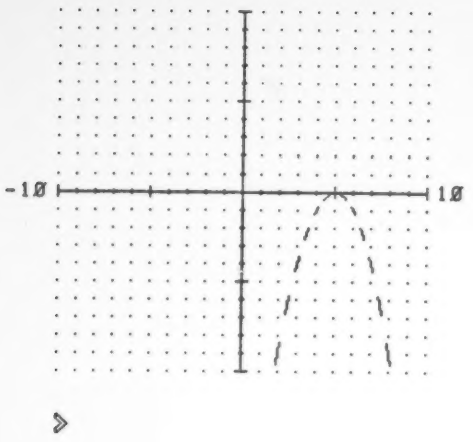
An alternative to this approach is to vary the specific item used at each drill presentation. In the presentation of a concept, the instances should vary as widely as possible in their noncritical characteristics (Gagné & Briggs, 1974). Providing examples having a wide range of variable attributes of a concept has been found to help students to learn generalizations across sets (Tennyson & Park, 1980). Instead of a drill with "n" fixed items, a sequence to teach a generalization should consist of "n" general classes of items. In the capitalization drill, there would be a general "foreign countries" item,

a general "state" item, a general "day of the week" item, etc. When an item was to be presented, an example from the general class would be given, which, again, might be "France" for the foreign country subclass. However, the iterations of items in review positions would then be modified to reflect the range of the concept. The actual drill items would be drawn from the pool of items that represent that particular concept class. When the foreign country subclass came up again, a different example representative of that subclass would be presented--perhaps "Peru" or "China." Thus, in this scheme, each drill presentation adds new information about the range of application for the subclass. This information is unavailable when fixed items are used. Generalized item selection should be more effective in teaching the student to respond correctly to <u>any</u> possible item from a given class.

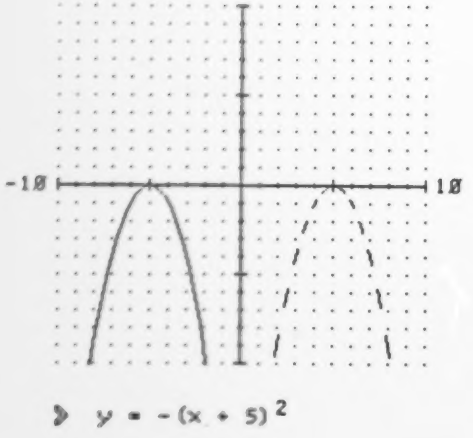
Siegel and Misselt (1984) suggest that improved drill techniques can be used to produce effective and efficient instruction of generalizable skills. The University of Illinois PLATO reading comprehension curriculum (Siegel, 1979; Siegel & Davis, 1984) employs an increasing ratio review drill with variable items, in order to focus the student's attention on the general relationships within the concept rather than on the particular examples used. This strategy was successful in teaching the students appropriate generalized reading skills (Alessi, Siegel, Silver, & Barnes, 1982). Siegel and Misselt outline three characteristics of such drills: (a) a single concept is taught, (b) the number of actual items in the queue is small and limited to the subclasses that form the task being taught, and (c) items are varied in review positions to demonstrate the range of the subconcept.

One major difference between generalized and paired associate drills is that generalized drills use variable items to demonstrate the range of the concept, while paired associate drills teach the specific items with a stipulated teaching set. The two kinds of drills must also differ in the type of feedback given. In a rote memorization drill, the only feedback necessary is of the most basic yes/no variety. The function of feedback in paired associate tasks is to report whether a response is correct or not, and in some cases, to provide the correct response. The feedback for a generalizable task, though, must provide more information. It must give the student item-specific corrective responses that tell whether the student's answer was correct or not, and it must also show how the item is an instance of the concept being taught.

For problem solving tasks, one such feedback technique is provided through "intrinsic models" (Dugdale, 1981). Intrinsic instructional models provide a working mathematical model to explore in which the skills to be learned are intrinsic to the task and in which diagnostic feedback is given directly and meaningfully without unnecessary verbiage. Parts of this model are used in the computer-based lesson "Exploring Simple Graphs" (Gilpin & Dugdale, 1979), which is designed to teach the relationship between the equations of curves and their graphs on the Cartesian plane. In the lesson, a curve is plotted on the screen (Figure 3a), the student supplies an equation at the arrow, and the computer plots the student's equation on the screen. The student's goal is to write the equation for a curve that, when plotted, will match the target curve exactly. Figure 3b shows an incorrect attempt, and Figure 3c shows the problem answered correctly. Because the student's trial



(a)



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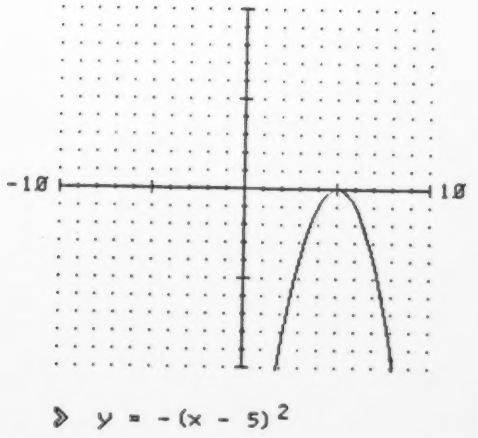


(c)

Figure 3. Intrinsic feedback model for identifying equations of graphs: (a) target graph; (b) incorrect attempt; (c) correct attempt.

equations and their graphs provide useful information in understanding how an error relates to the solution, they are left on the screen through subsequent trials. These trial answers are a powerful means by which relationships between curves and their equations may be learned.

A drill to teach a generalizable skill, such as mathematical problem solving, should combine the features of optimal drill procedures with the principles of concept teaching. The research objective for this study was to examine the effects of increasing ratio review and generalized item selection in a computer-based instructional drill meant to teach a generalizable concept.

METHOD

This study was designed to answer the following research questions: Is there any effect for increasing ratio review as opposed to immediate review only in drills that teach generalizable concepts? Is there any effect for generalized item generation as opposed to fixed items in a drill to teach generalizable concepts?

Design

This research studied the generalizations suggested by the relationship between the equations for curves, specifically parabolas, and their shapes on the Cartesian coordinate plane. Given the graph of a parabola, the general placement and orientation of the curve specify its basic formula, independent of its specific location on the plane. Curves with similar positioning and orientation may be thought of as instances of a general family of curves, all possessing those characteristics. The wide range of all parabolas can be grouped into several subclasses based on the position of the vertex, the relative "width" of the curve, the orientation on the Cartesian plane, and the various combinations of these characteristics. In the drill designed to teach these concepts, each class was a single "item" in the drill set according to the strategy outlined above. In other words, the drill items were specified by general characteristics rather than by specific exemplars.

For example, one class of graphs was described by the equation

$$y = x^2 - h^2 \text{, where } h > 0.$$

The equations

$$y = x^2 - 2$$
$$y = x^2 - 3$$
$$y = x^2 - 7$$

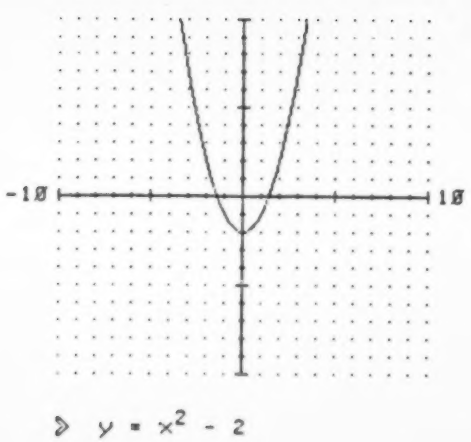
are all members of this class. Figure 4 shows their graphs. Each of these examples share the sameness of shape, orientation, and placement relative to the origin. Another class was described by the general formula

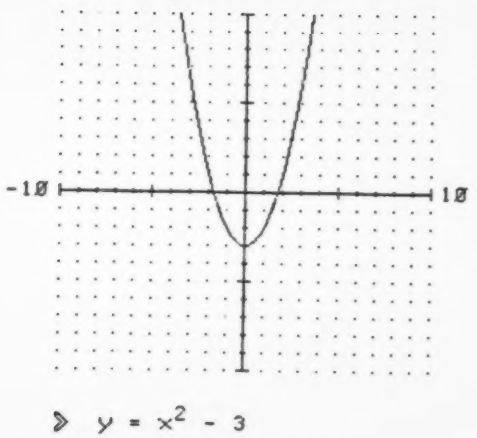
$$y = -(x - k)^2 + h \text{ , where } h > 0, k > 0.$$

The equations

$$y = -(x - 2)^2 + 3$$
$$y = -(x - 3)^2 + 4$$
$$y = -(x - 7)^2 + 1$$

are members of this class. Their graphs are shown in Figure 5. The sameness of the graphs within the classes shown in Figures 4 and 5 is nearly as clear as shown through the equations. Although the Gilpin and Dugdale lesson had 43 levels or subclasses, empirical evidence suggested that the level of detail specified by the 43 levels in the original lesson was more than was necessary. A later version used significantly





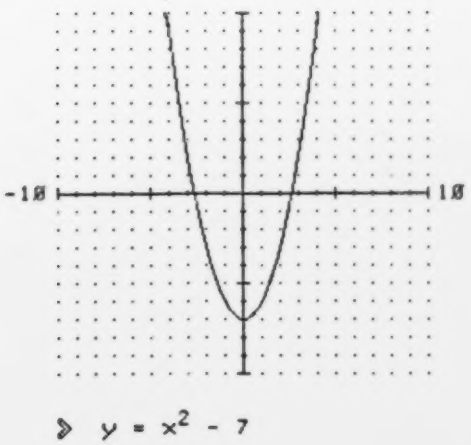
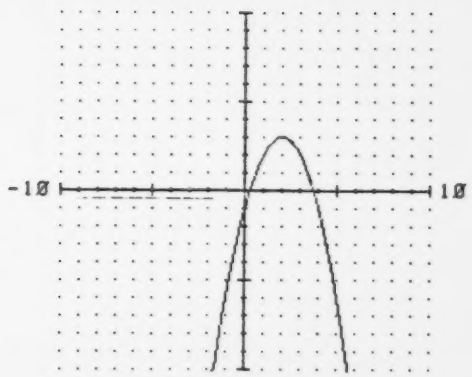
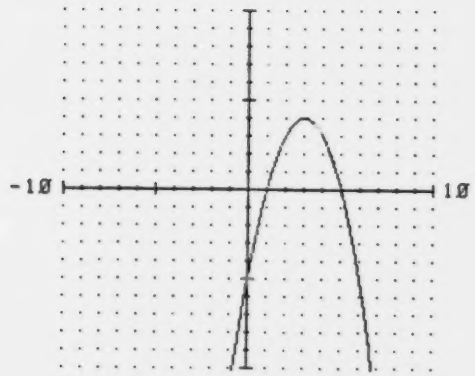


Figure 4. Three curves from the general class of parabolas identified by the equation $y = x^2 - h$, where $h > 0$.





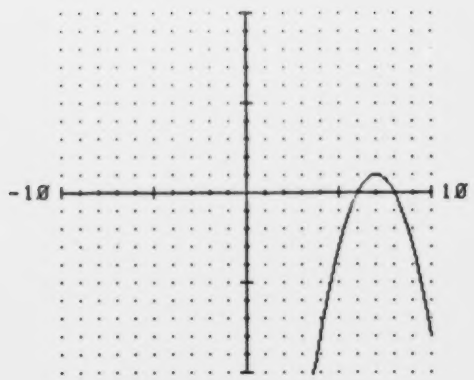


Figure 5. Three curves from the general class of parabolas identified by the equation $y = -(x - h)^2 + k$, where $h > 0$ and $k > 0$.

fewer levels. For this study, some levels were combined, and many were dropped entirely, so that there were 16 distinct levels that made up the drill set. The 16 levels are described in Figure 6. The instructional goal was to teach the generalizations involved in recognizing the relationship between the graphs and their equations.

For the purposes of the experiment, three drill paradigms were used: (a) increasing ratio review with generalized item generation (IRR-GEN), (b) increasing ratio review with fixed items (IRR-FIX), and (c) immediate review only with generalized item generation (IMM-GEN). In increasing ratio review with generalized items, items were randomly selected from the appropriate generalized class for each item presentation, and missed items were reviewed in a one-, three-, five-later review schedule which presented different items from the same class at each review. The increasing ratio review with fixed items paradigm selected a single item from each class at the beginning of the drill, and this one item was used at each presentation of that concept class. The immediate review only with generalized items drill generated the items in the same manner as in the first drill, but missed items were repeated immediately (one-later), until a correct response was given--but then placed at the end of the list. The immediate review only strategy corresponded to the sequencing in the original lesson.

These treatments were chosen to answer the research questions listed above. In a comparison of posttest scores, IRR-GEN as opposed to IMM-GEN should demonstrate the effect of increasing ratio review. A comparison of IRR-GEN and IRR-FIX posttest scores should examine the effect of generalized items versus fixed items.

1.	$y = x^2 - K$	(7)
2.	$y = -x^2 + K$	(7)
3.	$y = (x-K)^2$	(7)
4.	$y = -(x-K)^2$	(7)
5.	$y = (x+K)^2$	(7)
6.	$y = -(x+K)^2$	(7)
7.	$x = y^2 - K$	(7)
8.	$x = -y^2 + K$	(7)
9.	$x = (y-K)^2$	(7)
10.	$x = -(y-K)^2$	(7)
11.	$x = (y+K)^2$	(7)
12.	$x = -(y+K)^2$	(7)
13.	$y = \pm (x-K)^2 \pm J$	(112)
14.	$y = \pm (x+K)^2 \pm J$	(112)
15.	$x = \pm (y-K)^2 \pm J$	(112)
16.	$x = \pm (y+K)^2 \pm J$	(112)

K = (1,2,3,4,5,6,7)
J = (1,2,3,4)

Figure 6. General formulas for the 16 subclasses of parabolas. The number in parentheses indicates the total number of possible exemplars which could be generated.

Subjects

The experimental subjects were 51 subfreshmen enrolled in one of three Algebra I classes at a university laboratory high school. The same instructor taught all three classes and covered identical material in each. All subjects had received a brief introduction to a portion of the material covered in the lesson several months prior to the experiment. They were also told that their performance on the experimental material would not affect their course grades.

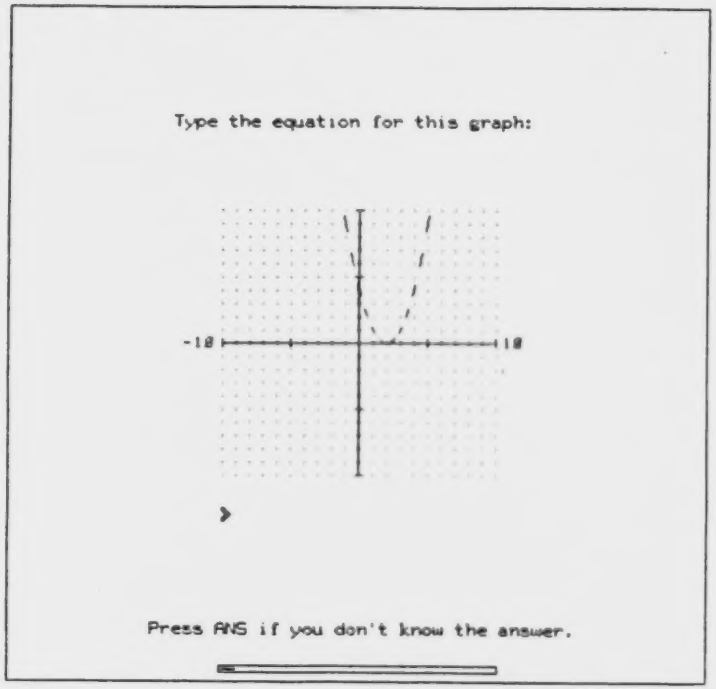
Procedure

The entire experiment was carried out in the normal class meeting times on three consecutive days. A 28-item written pretest was administered to all subjects prior to computer instruction. The test consisted of items presented in a format identical to that used in the computer-based instruction. For each problem, a graph was shown, and the student was to provide the equation for the graph. The majority of the test dealt with parabolas, although some simpler straight lines were included, as were several more advanced graphs--such as circles and hyperbolas. Subjects were given 12 minutes to complete the test. Each subject was given a written introduction to the terminal keyboard (Appendix A) and instructions for interacting with the computer (Appendix B).

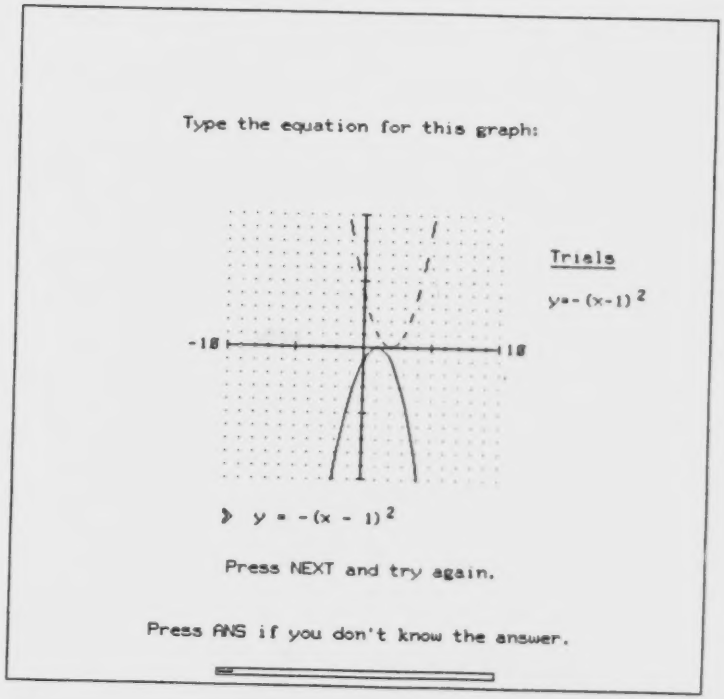
The following day, the computer-based instruction was administered to all students. The instruction was controlled by the University of Illinois PLATO IV Computer-based Education System (Smith & Sherwood, 1976). Upon signing on to the system, each subject was randomly

assigned to one of three treatment groups corresponding to the three drill models discussed above: increasing ratio review drill with generalized items (IRR-GEN), increasing ratio review drill with fixed items (IRR-FIX), and immediate review only drill with generalized items (IMM-GEN). Students from each class were distributed evenly across the three treatment groups.

Although most subjects had prior experience with the PLATO system, they were given an on-line introduction to the keyboard and a description of the lesson and its required tasks. All subjects, regardless of assigned treatment group, worked on the drill portion of the instruction for 30 minutes. The instructional format was based on that used in "Exploring Simple Graphs." The drill consisted of a series of problems presented in the sequence indicated by the particular drill paradigm used. For each item, a parabola was drawn on a grid on the terminal screen (Figure 7a), and the task was to type in the equation for that curve. The student's equation was graphed on the same grid. If the graphs did not match (Figure 7b), the student was given more chances to answer the item (Figure 7c) or could ask for the answer, but the item was considered incorrect and treated according to the particular drill parameters for that group. If the graphs matched on the initial attempt (Figure 7d), the equation was correct and the item was placed at the end of the stack of items, and the student progressed to the next drill item. A progress bar on the screen showed the proportion of the drill completed at any point. After the allotted time was up, each subject answered a few questions about his opinions of the lesson and the degree to which he had worked outside of class on the material.

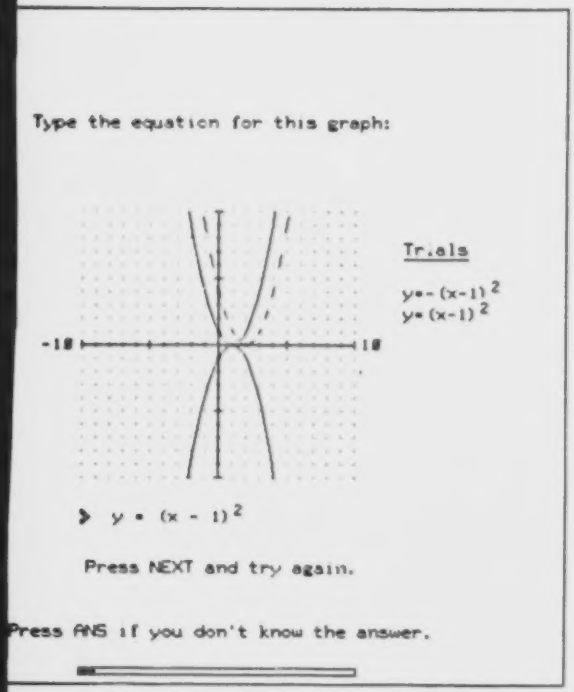


(a)



(b)

Figure 7. Screen displays from the instructional lesson: (a) initial problem presentation; (b) error on first attempt.



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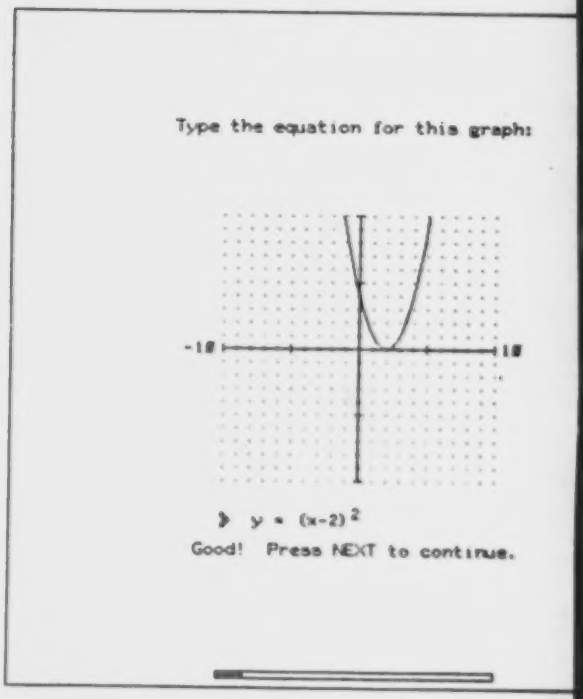

(d)

Figure 7 (cont.). (c) error on second attempt; (d) correct response.

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On the third day, all subjects took a 28-item posttest (Appendix C). The format was identical to the pretest, except that the items were exclusively graphs of parabolas. The parabolas tested were different from those on the pretest and were selected so that all levels were represented. Because each test item possessed features of several of the generalizations covered in the drill, each item was scored on a multiple point scale. For example, the correct answer for the graph in Figure 7a is $y = (x - 2)^2$. The incorrect answer in Figure 7b, $y = -(x - 1)^2$, if given on the posttest for that graph, would have been worth three out of five possible points. The student correctly identified the vertical (rather than horizontal) orientation, the lack of vertical displacement, and the direction of horizontal displacement. He lost two points for failing to give the correct upward orientation and inaccurately specifying the magnitude of the displacement. The incorrect answer in Figure 7c, $y = (x - 1)^2$, is missing only one of these characteristics and would have scored four out of five possible points. The scale for scoring ranged from four points for the simplest equations (e.g., $x = y^2 - 1$) to seven points for the most complicated equations (e.g., $y = -(x - 4)^2 + 3$).

RESULTS

Table 1 shows the observed group means and standard deviations for the pretest and posttest scores. The maximum possible score was 168. Even though the subjects were assigned to the treatment groups randomly, the chance distribution resulted in groups that were quite different in mean pretest scores. The posttest scores were analyzed using an analysis of covariance technique (Winer, 1971), with the pretest scores as the covariate. Table 2 shows the test of homogeneity of within-class regression. The critical value for a .10-level test is $\underline{F}_{.90}(2,45) = 2.43$. The observed $\underline{F}$ (.22) is far below this critical value. Thus, the experimental data do not contradict the hypothesis of homogeneity of within-class regression and do not rule against pooling the within-class regressions for the covariance model.

The results of the analysis of covariance of the adjusted group means are shown in Table 3. The experimental data indicated statistically significant differences between criterion scores for the three groups after the adjustment was made for the linear effect of the covariate ($p < .025$). Table 4 shows the adjusted group means. A Newman-Keuls multiple comparison test was performed on the adjusted group means using an adjusted average effective error per unit as the MS_{error}. The results of this procedure are given in Table 5. The IRR-GEN group adjusted posttest mean differed significantly from the IMM-GEN treatment group ($p < .025$). The difference in posttest performance between the IRR-FIX group and the IMM-GEN group was also significant ($p < .05$). There was no significant difference detected between the IRR-GEN group and the IRR-FIX group.

Table 1

Group Means and Standard Deviations for Pretest and Posttest Scores

Group[a]	Pretest	Posttest
IRR-GEN		
M	25.00	110.00
SD	20.00	42.19
IRR-FIX		
M	29.12	108.29
SD	22.06	42.07
IMM-GEN		
M	42.71	99.06
SD	25.58	43.24

Note. IRR-GEN = increasing ratio review with generalized items; IRR-FIX = increasing ratio review with fixed items; IMM-GEN = immediate review only with generalized items. Maximum possible score = 168.

[a] *n* = 17 for all groups.

Table 2

Test of Homogeneity of Within-class Regression

Source of variability	SS	df	MS	F
S_2	493.50	2	246.75	.22
S_1	50310.32	45	1118.01	
Total	50803.82	47		

Note. S_2 = variation of the individual within-class regression coefficients about the pooled within-class regression coefficient; S_1 = variation of the individual observations about the unpooled within-class regression lines.

Table 3

Analysis of Covariance of Adjusted Group Means

Source of variability	SS_{adj}	df	MS_{adj}	F
Treatments	8844.93	2	4422.47	4.09*
Error	50803.82	47	1080.93	
Total	59648.75	49		

Note. Error is the pooled within-class residual variation.

*$p < .025$

Table 4

Adjusted Group Means

Group	M
IRR-GEN	118.78
IRR-FIX	112.10
IMM-GEN	86.47

Note. IRR-GEN = increasing ratio review with generalized items; IRR-FIX = increasing ratio review with fixed items; IMM-GEN = immediate review only with generalized items.

Table 5

Results of Newman-Keuls Multiple Comparison of Adjusted Means

Group	1	2	3
1. IRR-GEN (M = 118.78)	-	6.68	32.31**
2. IRR-FIX (M = 112.10)		-	25.63*
3. IMM-GEN (M = 86.47)			-

Note. Cells indicate the absolute value of the differences among means. IRR-GEN = increasing ratio review with generalized items; IRR-FIX = increasing ratio review with fixed items; IMM-GEN = immediate review only with generalized items.

*$p < .05$. **$p < .025$.

DISCUSSION

The main effect for review schedule was as predicted. Treatments IRR-GEN and IMM-GEN were the same in that the subjects in both groups received generalized items and differed only in the review schedule for missed items. The first group had a spaced review schedule, while the other only reviewed an item immediately following an error before the item was returned to the end of the list. Clearly then, increasing ratio review accounted for the significant difference in delayed task performance. The systematic review of difficult items helped the IRR-GEN subjects to remember the concepts over time better than immediate review treatment helped the IMM-GEN group. The existence of this difference reinforces the findings concerning reviews in the original CFP study and also supports the claim that increasing ratio review techniques can be successful in enhancing traditional drills to teach generalizations.

The comparison between IRR-GEN and IRR-FIX should have demonstrated the effectiveness of using generalized items rather than fixed items in a concept drill. As it turned out, the adjusted mean posttest score for IRR-GEN was higher than for IRR-FIX, but not significantly so. At first, this finding, which suggests that the kind of items selected is not vital to the teaching of generalizations, seems to contradict directly the established theories of concept learning. A more plausible explanation of this observation is evident from an examination of the actual generalization taught and the method used. Although each class of parabolas was designed to convey a particular generalizable feature

of parabolas, the items in any one class also necessarily exhibited features contained in other classes. For example, the sign of the coefficient preceding the squared term in the general parabola formula determines which direction the curve will open. Levels 1 and 2 illustrate this for the functions of x and levels 7 and 8 illustrate this for the functions of y (see Figure 6). However, this leading coefficient is present in the examples from each of the other levels as well. Even though levels 13-16 primarily illustrate the combined horizontal and vertical displacement of the parabola from the origin, they also necessarily include variable examples of the generalizations presented in the initial levels which dealt with the direction in which the curve opened. Thus, even though the actual concept classes were distinct in that no example could appear in two classes, the generalizable features (the objects of instruction) were integrally associated with many classes. The subordinate concepts themselves were actually hierarchical in nature rather than at more or less equal levels. Even though fixed items were used in the instruction, the wider range of a concept was evident from the examples presented in other classes. Any effect for generalized items may have been masked because of the nature of the generalization chosen for the instruction.

It is also possible that the variation among teaching examples for a generalization is not as essential when presenting a rigidly-structured, rule-based generalization to sophisticated learners. The students' familiarity with mathematics may have been broad enough that both approaches were satisfactory in demonstrating the range of the overall generalization and the application of each of the subclasses.

The intrinsic model upon which the instruction was based probably also contributed to this effect. More so than in the feedback procedures used in many drill paradigms, the intrinsic feedback conventions conscientiously accentuate the broader ideas upon which the material is founded when giving feedback to particular student responses. Those who understood the feedback probably also understood the generalizations implied by the items, regardless of whether the particular items varied across the range or not. Perhaps the structure of the task and the effects of the feedback were so strong as to cover the effect of generalized versus fixed items.

The significant difference between IRR-FIX and IMM-GEN provides more evidence that supports the effectiveness of increasing ratio review. Even with a limited teaching set, the IRR-FIX group was able to perform better on a generalized task one day after instruction than the group trained with generalized items but under a less effective review paradigm.

CONCLUSIONS

The familiar drill and practice instructional format should not be overlooked as a powerful instructional use of computers. In this study, the seemingly incompatible techniques of an intrinsic feedback discovery approach to instruction and an efficient and sophisticated drill paradigm were combined to create an effective instructional lesson. Clearly, careful sequencing of items according to an increasing ratio review schedule is a powerful means to develop recall of information. This effect is present for both rote memorization tasks and generalizable skills. In the design of computer-based drills for generalizations or for paired associates, increasing ratio review will increase the effectiveness and efficiency of the instruction. The actual long-term effects of optimized drill paradigms should be investigated in subsequent research.

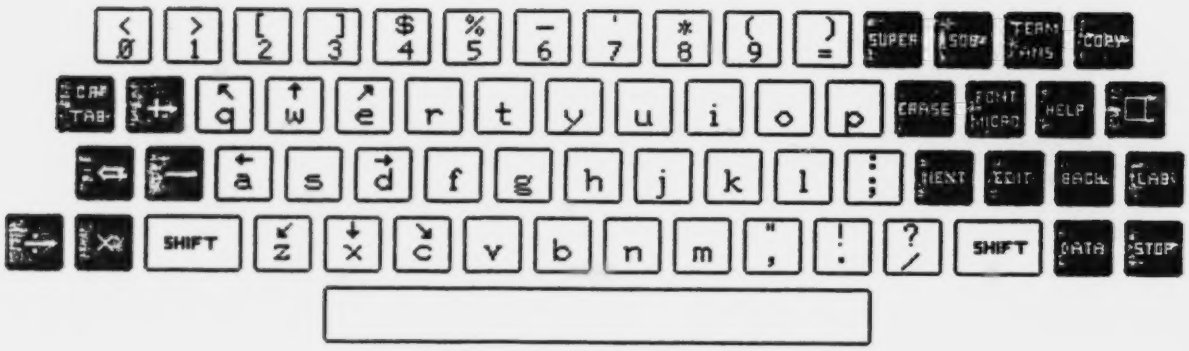
The value of generalized item selection strategies for generalized drills should also be studied in greater detail. The actual importance of item selection must be investigated in situations where the concept subclasses are more fully independent and where the range of application of these concepts is not as obvious from single concept instances. A concept in which the subordinate concepts are more clearly discriminated from one another by the critical attributes may be a better content area in which to examine the effect of generalized items.

Beyond generalizable drills, CFP techniques should be investigated in their application to optimizing the presentation of new items and the review of difficult items across separate instructional sessions.

Further development of CFP may enhance the usefulness of computer-based instruction by utilizing optimal drill techniques as specialized segments of larger programs to teach higher cognitive processes. Extensions of CFP drill strategies, from the traditional paired associate flashcard drills to the teaching of simple concepts and sophisticated mental operations via computer, will increase the utility of computers in the schools and improve the efficiency and effectiveness of teaching these skills.

APPENDIX A

The PLATO Keyboard



The letter and number keys on the PLATO keyboard are very much like the keys on a typewriter. Use these keys along with the mathematical operators found on the left of the keyboard to type equations just as you would write them. You should particularly know where to find +, -, /, =, (,), x, y, and the numbers 0 through 9.

The function keys on the right are important for interacting with PLATO. The following keys will be useful to you:

NEXT Press NEXT when you are finished typing your answer and you want PLATO to judge it.

ERASE Use ERASE to change your answer before you press NEXT. Each time you press ERASE, a single letter or number will be erased from the end of your answer.

SUPER Press SUPER before a number you want to be an exponent. To type "x^2" you would press x,SUPER,2.

ANS Press ANS (marked TERM/ANS) when you want PLATO to tell you the answer to a problem.

APPENDIX B

Instructions for Using PLATO

Signing on to the system

1. When you sit down at a terminal, the screen will say "Press NEXT to begin." Press the NEXT key.

2. The next screen display will show the date and time and ask you to type your PLATO name. Your PLATO name is your last name followed by a space and your first initial, written completely in lower case letters.

   For example, Alice Thompson would type:

   thompson a

   (Notice there are no capitals or punctuation marks in your PLATO name.)

   Type your PLATO name. Then press NEXT.

3. The next screen display will ask for your PLATO group. The group for your class is

   unigraph

   (Again, there are no capitals or punctuation marks in your group name.)

   Type your group name, and then, while holding down the SHIFT key, press the STOP key.

After completing this sign on process, you will be taken directly to the instructional lesson.

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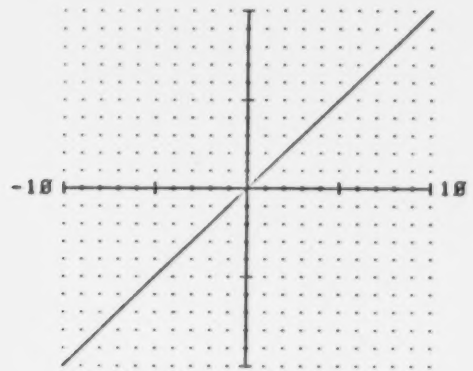
Name _____, _____
Last Name First Initial

Form B1

DO NOT OPEN THIS TEST BOOK UNTIL TOLD TO DO SO!

Directions: For each graph, write the equation in the blank.
If you don't know the answer, skip that problem.

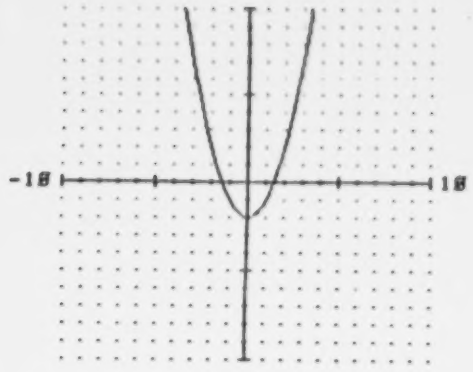
Example:



$y = x$

There are 28 problems. You will have 12 minutes to complete this quiz. When the proctor calls "STOP," stop working immediately and close your book.

Raise your hand if you have a question during the test.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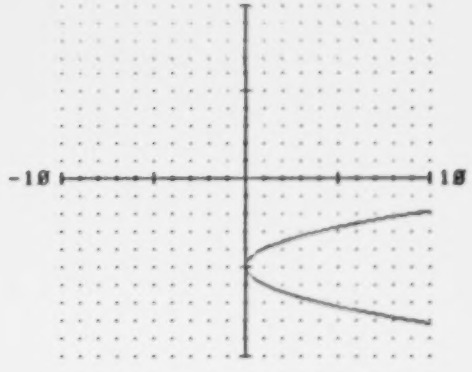
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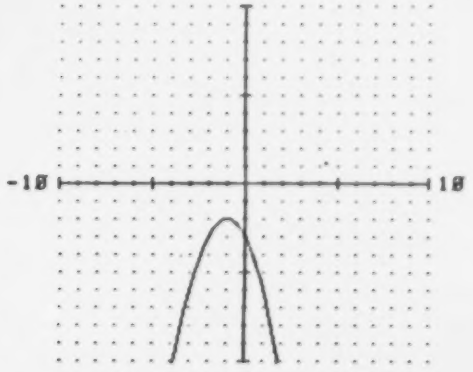
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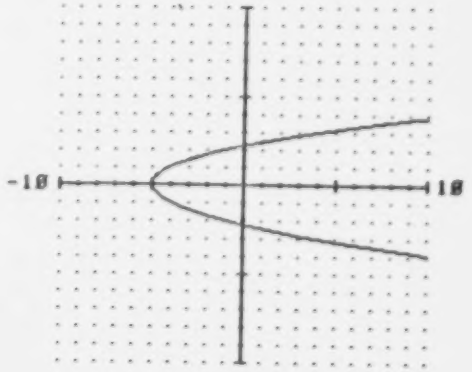
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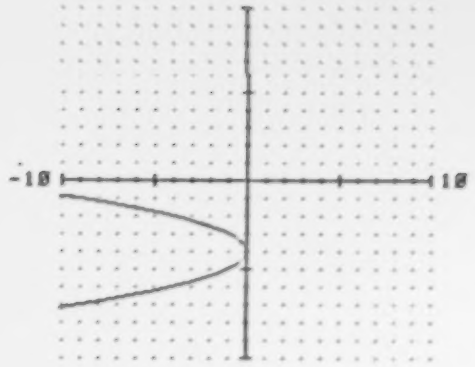
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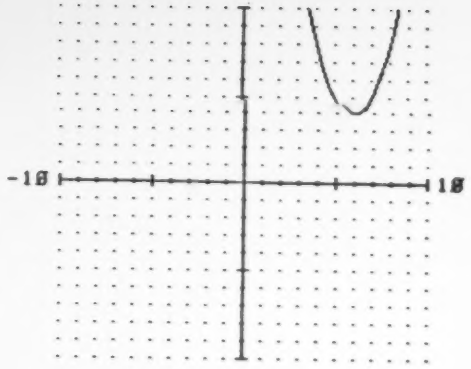
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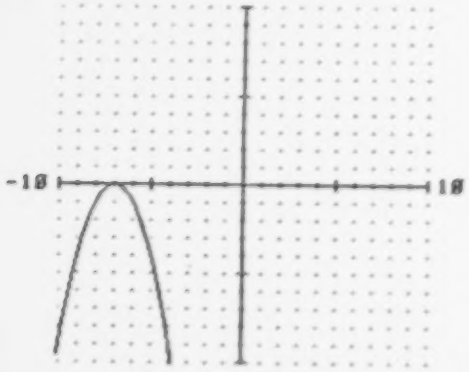
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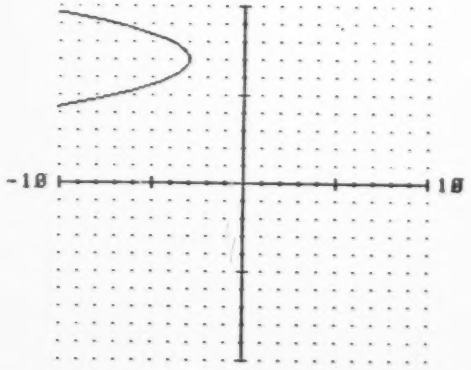
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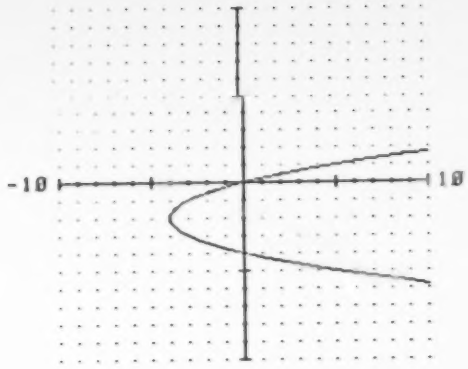
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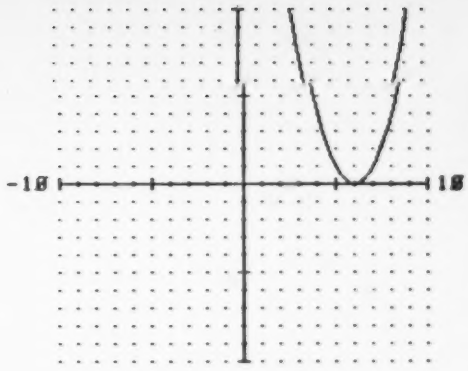
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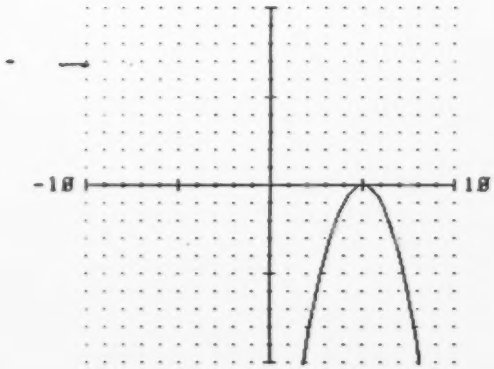
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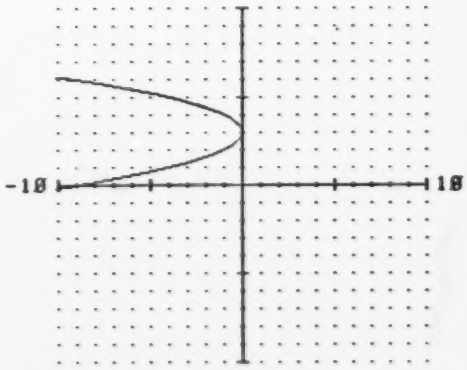
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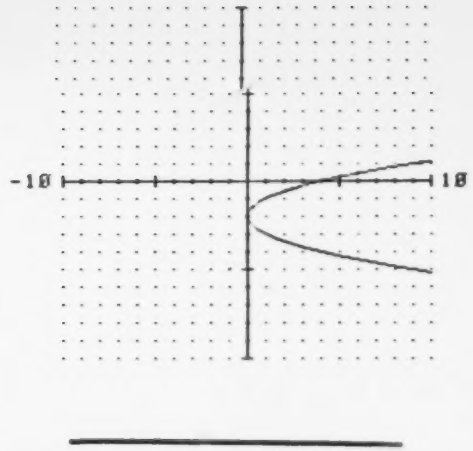
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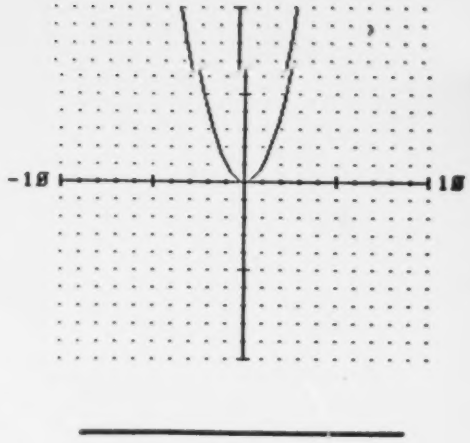
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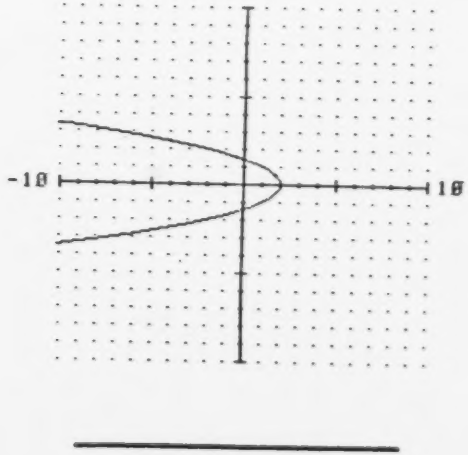
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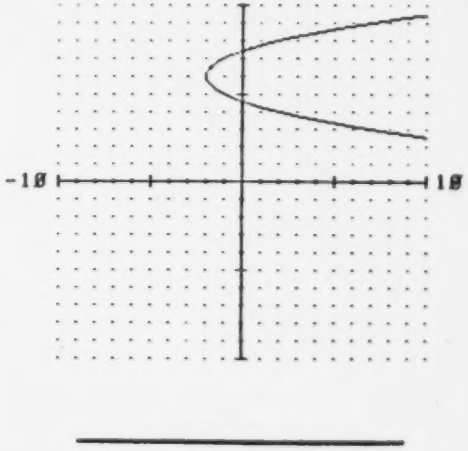
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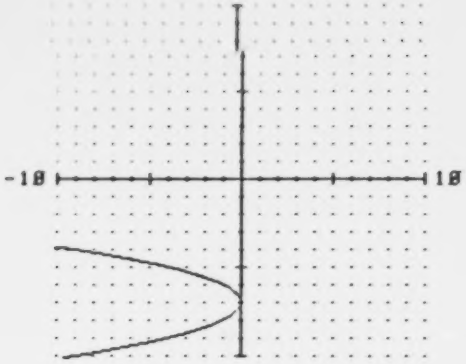
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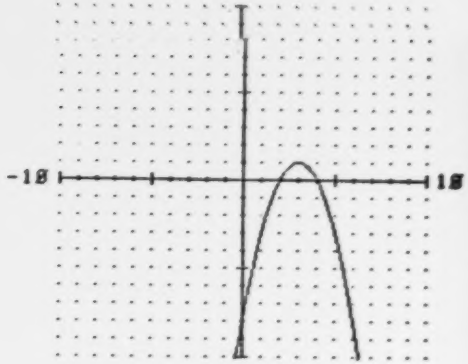
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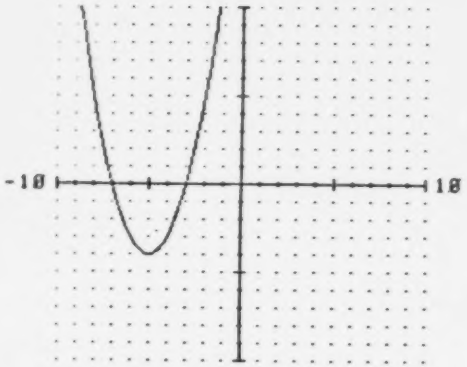
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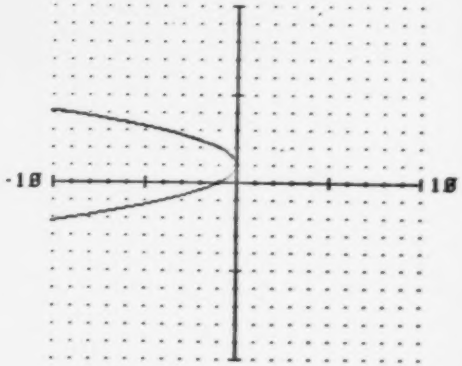
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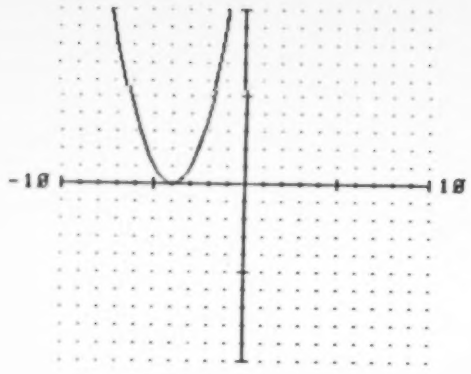
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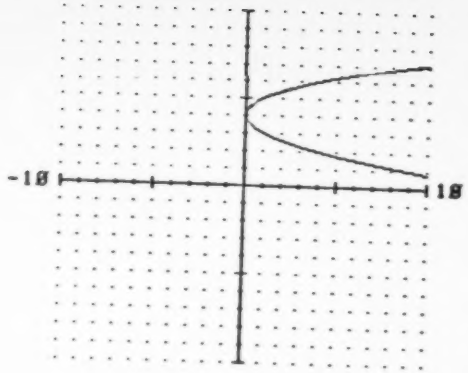
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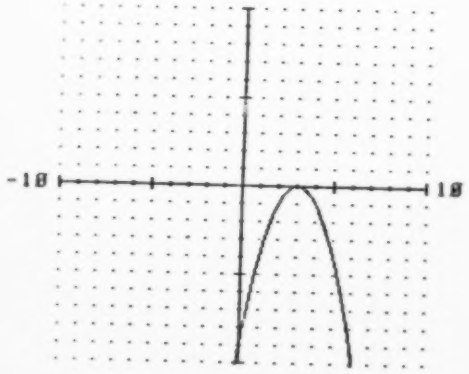
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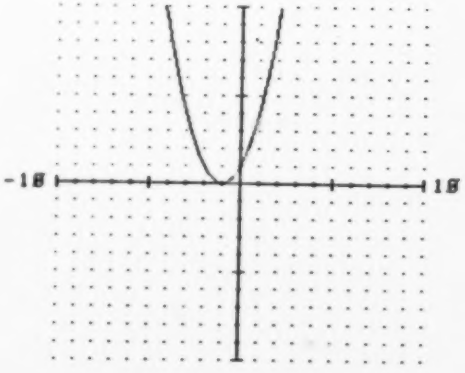
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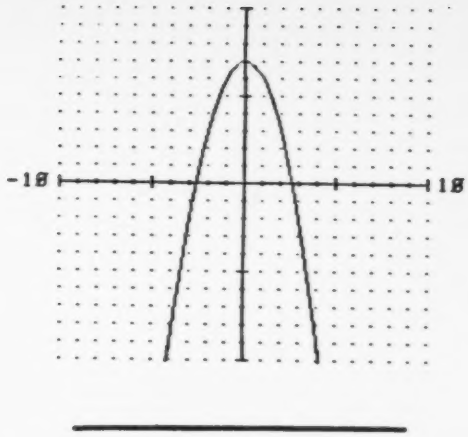
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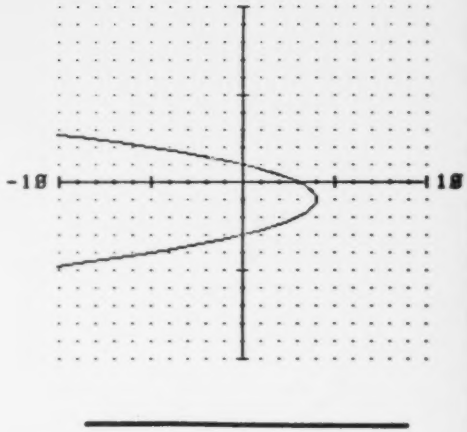
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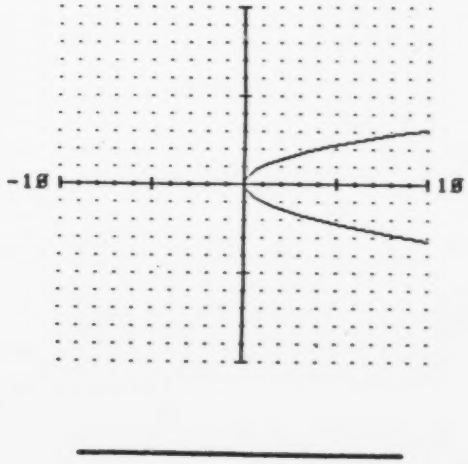
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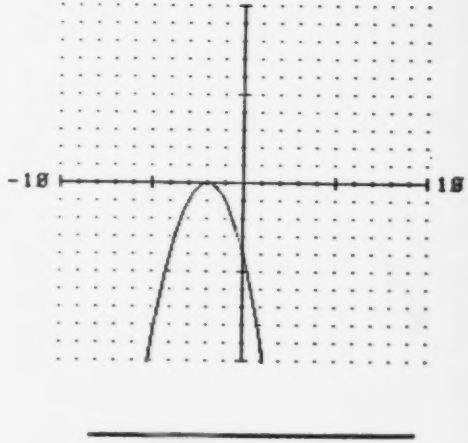
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LIST OF REFERENCES

Alessi, S., Siegel, M., Silver, D., & Barnes, H. (1982). The effectiveness of a computer-based reading comprehension program for adults. Journal of Educational Technology Systems, 11(1), 43-57.

Atkinson, R. C. (1972). Ingredients for a theory of instruction. American Psychologist, 27, 921-931.

Atkinson, R. C. (1974). Teaching children to read using a computer. American Psychologist, 29, 169-178.

Atkinson, R. C., & Crothers, E. J. (1964). A comparison of paired-associate learning models having different acquisition and retention axioms. Journal of Mathematical Psychology, 1, 285-315.

Balajthy, J. (1984). Reinforcement and drill by microcomputer. The Reading Teacher, 37, 490-494.

Dear, R. E., Silberman, H. F., Estavan, D. P., & Atkinson, R. C. (1967). An optimal strategy for the presentation of paired-associate items. Behavioral Science, 12, 1-13.

Dugdale, S. (1981). Green globs: A microcomputer application for graphing of equations (CERL Report No. E-21). Urbana, IL: University of Illinois, Computer-based Education Research Laboratory.

Engelmann, S. (1969). Conceptual learning. Sioux Falls, SD: Adapt Press.

Engelmann, S., & Carnine, D. (1982). Theory of instruction: Principles and applications. New York: Irvington.

Gagné, R. M., & Briggs, L. J. (1974). Principles of instructional design. New York: Holt, Rinehart, and Winston.

Gilpin, J., & Dugdale, S. (1979). Exploring simple graphs [Computer Program]. Urbana, IL: University of Illinois, Computer-based Education Research Laboratory.

Klausmeier, H. J., Ghatala, E. S., & Frayer, D. A. (1974). Conceptual learning and development. New York: Academic Press.

Merrill, M. D., & Tennyson, R. D. (1977). Teaching concepts: An instructional design guide. Englewood Cliffs, NJ: Educational Technology Publications.

Merrill, P. F., & Salisbury, D. (1984). Research on drill and practice strategies. Journal of Computer-based Instruction, 11, 19-21.

Park, O., & Tennyson, R. D. (1980). Adaptive design strategies for selecting number and presentation order of examples in coordinate concept acquisition. Journal of Educational Psychology, 72, 362-370.

Siegel, M. A. (1979). Teacher's guide to the PCP reading comprehension program for adolescent and adult learners (CERL Report No. E-3). Urbana, IL: University of Illinois, Computer-based Education Research Laboratory.

Siegel, M. A., & Davis, D. M. (1984). Redefining a basic CAI technique to teach reading comprehension. Unpublished manuscript, University of Illinois, Urbana.

Siegel, M. A., & Misselt, A. L. (1984). Adaptive feedback and review paradigm for computer-based drills. Journal of Educational Psychology, 76, 310-317.

Smith, S. G., & Sherwood, B. A. (1976). Educational uses of the PLATO computer system. Science, 192, 344-352.

Tennyson, R. D., & Park, O. (1980). The teaching of concepts. Journal of Educational Research, 50, 55-70.

Tiemann, P. W., & Markle, S. M. (1983). Analyzing instructional content: A guide to instruction and evaluation (2nd ed.). Champaign, IL: Stipes.

Winer, B. J. (1971). Statistical principles in experimental design (2nd ed.). New York: McGraw-Hill.

Yates, D. S. (1983). In defense of CAI: Is drill-and-practice a dirty word? Curriculum Review, 22(5), 55-57.